Mr. Walker, in his Adams Prize Essay for 1865, p. 268, says: "it is worthy of remark that the portion of the year when the magnetic force is the greatest, and the direction of the needle most vertical in *both* hemispheres, coincides with that at which the earth is nearest to the sun and moves with the greatest velocity in its orbit. This fact furnishes another argument against the theory that these effects are due to *temperature*, as in that case they ought to occur at *opposite* periods of the year in the two hemispheres, whereas in fact they occur at the same period in both." The writer was doubtless misled by the annual variations in declination and horizontal force, which are evidently dependent upon the relative temperature of the northern and southern hemispheres. But if all the magnetic effects are primarily due to thermal and gravitating motion, it is evident that the *total* magnetic force must depend upon the *total* current producing energy of the sun, which is, of course, a maximum when "the earth is nearest the sun, and moves with the greatest velocity in its orbit." The argument which was considered conclusive against the theory, is, therefore, wholly in its favor.

THE CAUSES OF *Regional Elevations and Subsidences*, by LIEUT. C. E. DUTTON.

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Lieut. C. E. Dutton, desired to submit certain views, which he had been led to entertain, respecting the causes of regional elevations and subsidences. He was unacquainted with any views on this subject in the writings of geologists, which seemed to be satisfactory. In reflecting upon the nature of metamorphic rocks, and the probable changes which they had undergone, he thought that the facts brought to light by the researches of Bischoff, Daubrée, Sorby, Sterry-Hunt and others in that field, might contain, also, a solution of the unexplained problem of elevations and subsidences. It is now a generally accepted opinion among writers upon chemical geology, that metamorphic rocks have reached their present condition, through the combined agencies of heat, pressure, and water, acting upon sedimentary strata; that sulphur, carbonic acid and volatile chlorides and fluorides have played highly important parts under similar conditions, and that soluble earths and metallic salts and vapors have had no inconsiderable influence upon the totality of changes. That water especially, under the influence of a moderately high temperature and great pressure, is capable of changing in a wonderful manner the structure and arrangement of rocky materials of all kinds, has been abundantly shown by innumerable synthetical experiments, a great number of which have been summed up by Daubrée in an able memoir on the subject to the French Academy. He has also shown that minerals, which,

under ordinary temperatures to which water is subjected, are in no respect changed, may be completely altered by water confined in strong vessels and heated to dull redness. Silicates, aluminates and calcareous matters in the amorphous condition, may not only be made crystalline, but their degrees of hydration may also be permanently altered; and he also mentions the production of anthracite by a similar process, from wood. Indeed, the changes both of structure and chemical constitution, which may be produced in this manner, are very great, and extend, in all probability, to nearly the whole range of mineral matters found in the rocks.

Now, if as is generally believed and accepted, these are the changes in progress, while rocks are undergoing metamorphism, then, in all probability, the rocks are undergoing at the same time *a change in their specific gravity*. It is highly probable, if water is the chief reagent, and if it constitutes a change both chemical and physical, that the specific gravity of the mass, into which it enters, is not the same as it was before such a change took place. But if we admit this, then we have also admitted that the volume of those rocks has either increased or diminished. If we assume it to have increased, there must take place an expansion, and such an expansion must necessarily be upward. For, beginning at the lowest level, at which any such change may be assumed to supervene, the total weight of the superincumbent mass is the same as it was before, and hence there would be no change at that level. Nor could there be lateral expansion of any importance; all expansion would of necessity be vertically upwards. On the other hand, a decrease of volume would occasion a subsidence for converse reasons.

If we were to assume a change in the specific gravity of 1000 feet of rock, to the extent of five per cent., we could account for a change of level of 50 feet, and a series of rocks as thick as the carboniferous in this State, would, with an equal amount of change, give an alteration of level equal to the average attitude of the North American Continent above the ocean. It is, of course, impossible to conjecture the depth to which metamorphic action may extend, though it is undoubtedly very great; at least eight or ten miles, and there might be no great improbability in supposing such changes to take place through a large portion of that depth at the same time.

That the rocks far down below the surface take up under the influence of great pressure, aided no doubt by heat, large quantities of water, carbonic acid, sulphydric acid, and perhaps other electro-negative agents, is manifest in the materials issuing from volcanoes and from thermal springs. Water and gaseous acids issue in such enormous quantities from volcanoes, as to constitute a large fraction of the entire mass delivered, indicating that the solid materials have become super-saturated with them, and the association is resolved as soon as they reach the surface of the earth, and are relieved of the pressure to which they have been subjected.

The overflow of volcanoes would, it is suggested, be susceptible of a similar explanation. Let us suppose a stratum or two, situated a few miles

below the surface, became softened or lightened by the combined agencies described, so as to be specifically lighter than the average mass of over-laying rock. If a vent or fissure could be found, such a plastic mass would inevitably follow the laws of the equilibrium of fluids, and would not only rise up into the chasm, but overflow. Putting the problem into another form, the heavier over-lying mass would sink into the lighter semi-fluid beneath, and drive it upwards. It is a well known fact, that the lavas are all of small specific gravity. Indeed, were it otherwise, Lieut. Dutton thought that the overflow of a lofty volcano like Ætna or Mauna Loa, would be impossible; for a column of dense material of such a height, exerting its pressure upon its subterranean reservoir, would raise the overlying strata, instead of rising above them. But, in truth, the superior strata are doubtless heavier, and exert a greater pressure upon the reservoir than the lava itself.

In a similar manner Lieut. Dutton sought to explain the intrusion of traps, trachytes and basalts. These rocks were probably lighter than those which originally overlaid them, and forced their way through weak places to the surface. The traps, basalts and porphyries,—at least such porphyries as may be called intrusive—though they are unquestionably altered sediments, are for the most part amorphous, and not crystalline. They were evidently altered at a comparatively low temperature, and at no very great depth. They do not appear to affect the strata into which they are intruded, and withal, are less highly metamorphic than gneiss or marble. Water seems to have been the chief agent in their transformation, and they may have been forced upward in a soft condition, and upon being relieved of the pressure, parted with the greater portion of this water. The traps and basalts also exhibit many planes of cleavage, with very perceptible interstices, and these interstices would seem to be much wider than could be accounted for by the contraction of cooling. He stated that he had often noted this fact, and was decidedly of the opinion that the contraction of these rocks by loss of heat, could by no means account for the entire width of such plans of cleavage, and believed that it was in great part due to the loss of water, which had once rendered them plastic.

If these views be correct, then we ought to expect that volcanic regions will be confined to those areas which have recently been regions of marked elevation. And we find this to be the case. In America, the whole extent of the Rocky Mountains and of the Andes, so far as known, was covered by the ocean at the beginning of the Tertiary period. The elevation of the Rocky Mountains was probably earlier than that of the Andes, and sooner completed. Hence, while the former was the scene of an unparalleled amount of volcanic action during the Pliocene and Miocene, and is now nearly, or quite, quiescent, except in Southern Mexico, the Andes still abound in active volcanoes. The East Indian volcanic regions are all of Tertiary formation, as are those of the Mediterranean and the Auvergne.